- Mechanical Properties of Irradiated Polarization-Maintaining Optical Fibers

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ABSTRACT

Polarization-maintaining optical fibers, referred to as PANDA fibers, were subjected to Cobalt 60 radiation (300,000 Rad). The mechanical properties of the PANDA fibers were measures after exposure to gamma radiation and compared to non-irradiated PANDA fibers. Mechanical testing, static loading and sonic modulus (a non-destructive technique) were used to examine the irradiated fibers. The mechanical properties of the irradiated PANDA fibers were determined to be the same, within statistical significance, to the non-irradiated PANDA fibers. Qualitative observations such as slight hardening of the acrylic jacket of the irradiated PANDA fiber appeared to have no significant effect on the mechanical properties.

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.INTI?ODUCTION

The use of polarization-maintaining (PM) optical fibers has increased over the last several years. These fibers are also being considered for applications in space crafts as fiberoptic rotation sensors where they could potentially be exposed to radiation. The effects of radiation on PM fibers has become an area of increased research activity [1-3] since their performance in radiation environments has to be evaluated for these fibers to be mission qualified. The reliability of I'M fibers in space radiation environments has led to several studies that have shown PM fibers to be more susceptible to ionizing radiation when compared to radiation hardened pure silica fibers[4]6.

Conventional, i.e., non-PM optical fibers, have been exposed and tested to determine the effects of low-earth orbit space environments on optical fibers'. Commercially available fibers consisting of plastic-clad, large-core, graded index and , single-mode were flown aboard the Long Duration Exposure Facility (LDEF) to determine the effects of ionizing radiation, temperature cycling, and polymer aging.

The effects of radiation on the mechanical properties of optical fibers has not been examined in a systematic manner. Most studies[8,9] on single mode fibers have focused on the effects of radiation on the optics of the fibers. Similarly for PM fibers, which are now being considered for space flight applications, the effects of radiation have been examined[1-3] in terms of attenuation ant] polarization holding properties and no studies regarding the effects of radiation on mechanical properties have been reported in the open literature.

A new type of PM fiber is being considered for advanced space craft inertial reference units as fiberoptic rotation sensors. This type of PM fiber, often referred to as a PANDA fiber, is significantly different from commercial optical fibers in two major ways. First, commercial optical fibers generally consist of a wave guide surrounded by an acrylic jacket. In the PANDA fiber, there exists a silicone layer between the wave guide and the jacket. Secondly, the PANDA fiber contains two beryllium oxide stress rods around the wave guide core that produces a stressed wave guide core specific for polarized light.

in this research, PANDA fibers were subjected to Cobalt 60 radiation (300,000 Rad) and their mechanical properties were measured after radiation exposure and compared to non-irradiated PANDA fibers. Sonic modulus - a nondestructive test technique - was used as alternative method to measure the modulus of the irradiated PANDA fibers.

EXPERIMENTAL APPROACH

'l'he modulus of the irradiated PANDA fibers was determined by three techniques. In the first, the engineering modulus was obtained from mechanical testing using an Instron Model 4505. In the second technique, static loading to generate stress-strain curves from incrementally increased loads on suspended fiber samples was used. 'l'he third technique involved a nondestructive test technique - sonic testing - using a Morgan Instruments Model PPM-5R Dynamic Modulus 'I'ester to measure the modulus. In the sonic modulus technique, sound waves are propagated through the fiber sample and the time for the sound wave to travel a fixed distance is measured. From the time versus distance the velocity of the sound wave traveling through the fiber sample is calculated. Using the density of the fiber sample, the sonic modulus is calculated as $E_c = \rho \times v^2$ where E_c is the sonic modulus, ρ is the density of the fiber, and v is the velocity of the sound wave. All testing conducted on irradiated PANDA fibers was also conducted on non-irradiated PANDA fibers and comparisons between the two were made. A qualitative observation was made that the irradiated PANDA fiber appeared to have a slight hardening of the acrylic jacket **when** compared to the non-irradiated PANDA fiber.

RESULTS AND DISCUSSION

Figure 1 shows a comparative plot of stress versus strain for irradiated and non-irradiated PANDA fibers. The modulus values determined from mechanical testing of the irradiated PANDA fiber was 1.55 x 106 Psi which was found to the same within statistical significance to the modulus of the non-irradiated PANDA fiber (I .57 x 10^6 Psi).

Figure 2 shows a comparison of the modulus of both the irradiated and non-irradiated PANDA fiber determined by the static loading technique. The modulus of the irradiated PANDA fiber was found to 3.42 x 106 Psi compared to 2.17 x 10^6 Psi for the non-irradiated PANDA fiber. This difference might be attributed to the slight hardening of the irradiated PANDA fiber acrylic jacket.

Table 1 shows the modulus of both irradiated and non-irradiated PANDA fibers determined from sonic techniques - a nondestructive method - in comparison to modulus values obtained by mechanical testing and static loading. Good agreement is observed among the three techniques where the modulus is seen to range from 1.55 x 106 Psi to 3.42 x 10’ Psi.

The modulus of the both the irradiated and non-irradiated fiber (3.00 x 10^6 Psi) demonstrated the utility of nondestructive techniques in determining the mechanical properties of optical fibers. The slight hardening of the acrylic jacket of the irradiated PANDA fiber appeared to only affect the modulus value determined by static loading.

CONCLUSIONS

The modulus of polarization-maintaining optical fibers, PANDA fibers, that were exposed to Cobalt 60 radiation (300,00 Rad) was determined by three techniques. Mechanical testing, static loading and sonic testing - a nondestructive technique- were used. The modulus values of the irradiated PANDA fiber were found to have no significant difference in comparison to the modulus values of the non-irradiated PANDA fibers even though the acrylic jacket of the irradiated PANDA fiber seem to have hardened slightly.

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TABLE 1

Modulus **Values** from **Different Techniques**

Modulus (Psi)

	Irradiated	Non-irradiated
Mechanical Testing	1.55 x 10^6	1.57X 10’
Static Loading	3.42x 10’	2.17x 10’
Sonic Testing	3.00 *x* 10’	3.00 *x* 10’

FIGURE 1

STRESS-STRAIN CURVES OF IRRADIATED AND NON-IRRADIATED PANDA FIBER

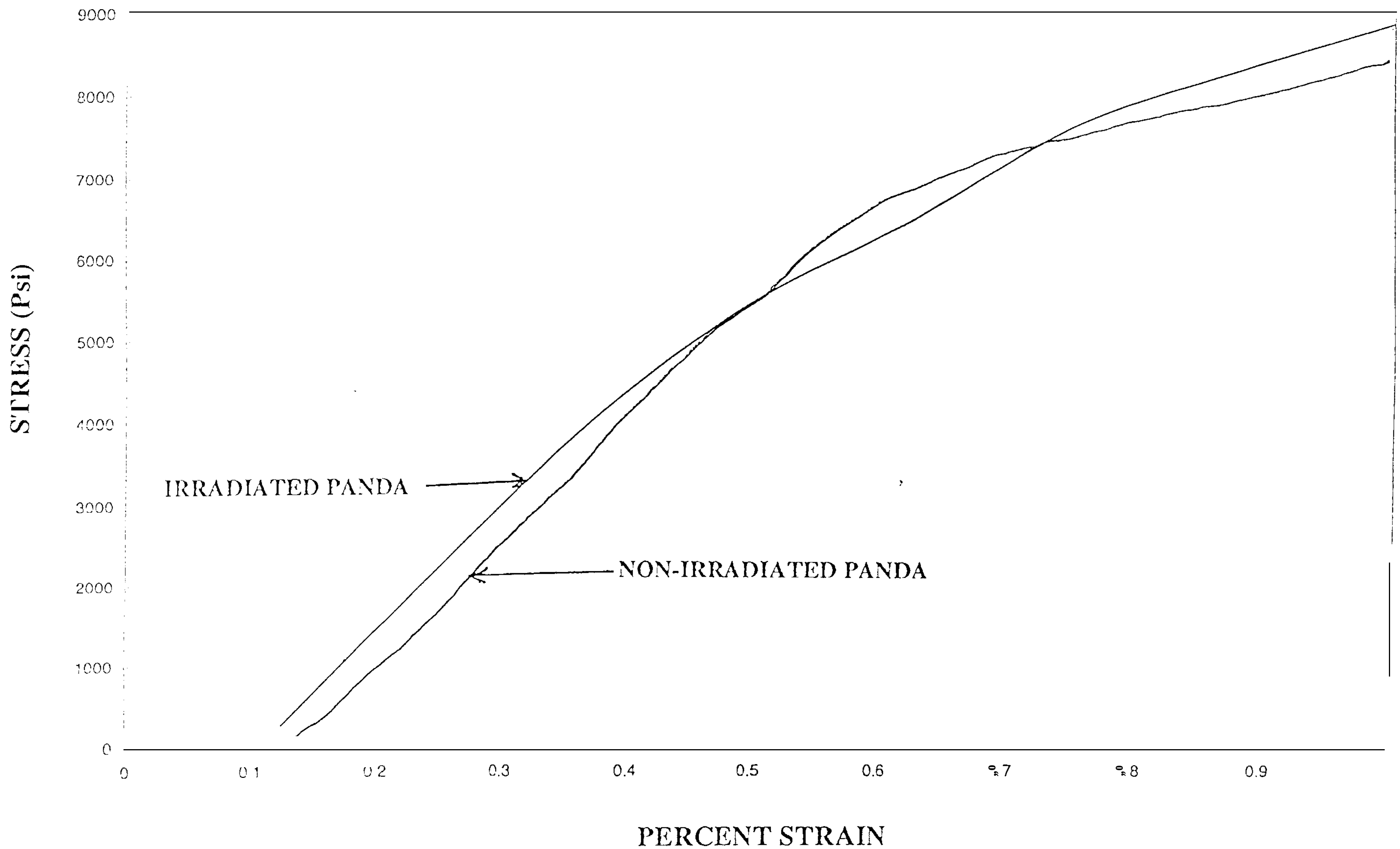
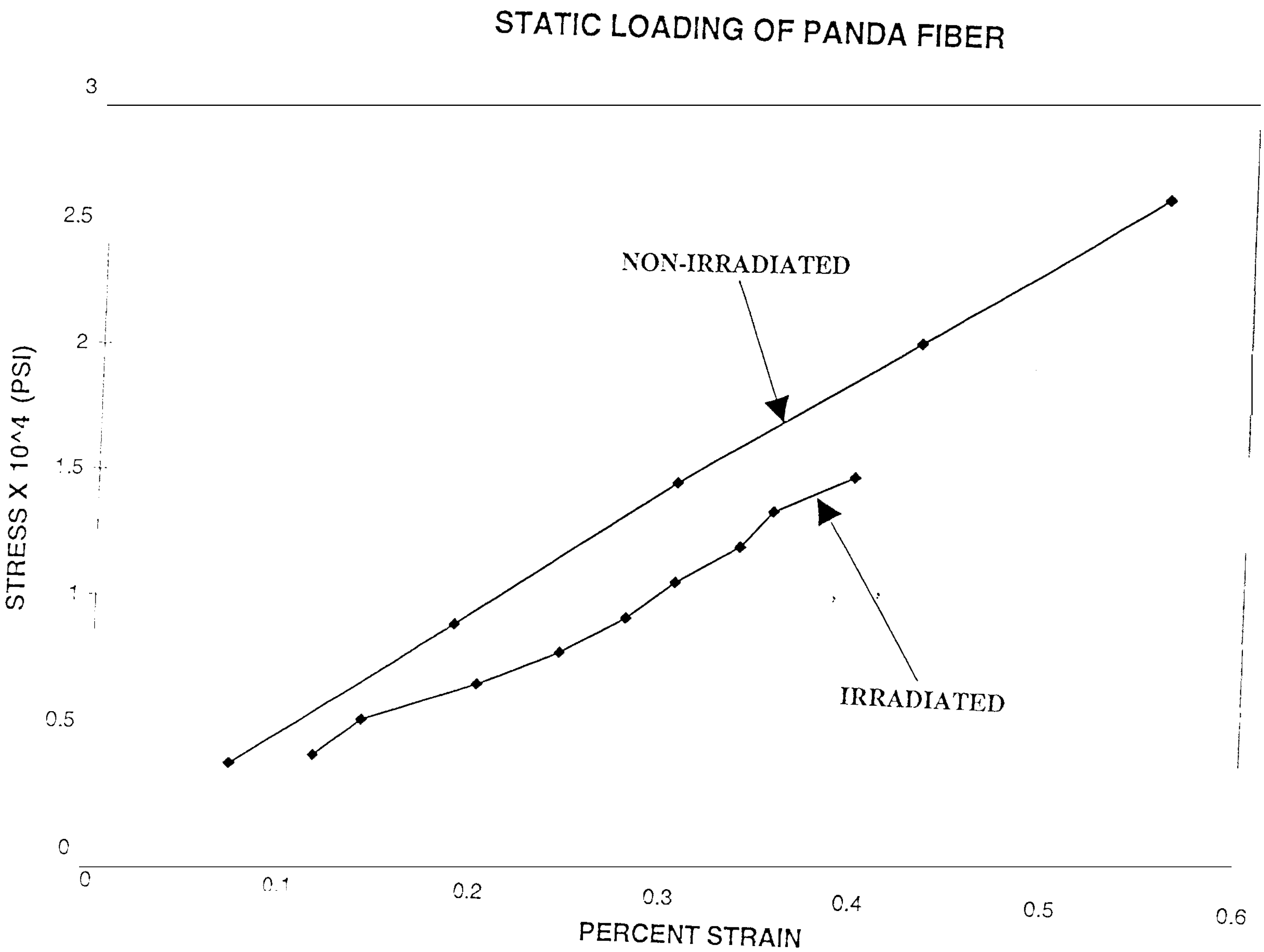


FIGURE 2


STATIC LOADING OF PANDA FIBER
STRESS X 10^4 (PSI)
3
2.5
2
1.5
1
0.5
0
NON-IRRADIATED
IRRADIATED
0
0.1
0.2
0.3
0.4
0.5
0.6
PERCENT STRAIN